loins. The *os ſacrum*, as well as the *os pubis*, imperfectly offified. All its joints are very rigid and ſtiff. It has no *anus*, but paſſes off its water in the natural way. Its *ſternum* is very imperfect; and it has no *clavicula*. It ſeems inſenſible of pain, not removing its arms or legs, if laid in an uneaſy poſture.

LXI. *An Account of the Phænomena of* Electricity in vacuo, *with ſome Obſervations thereupon, by Mr.* Wm. Watſon, *F. R. S.*

To the Royal Society.

Gentlemen,

Read Feb. 20, 1752. IN a paper I had the honour to lay before you in January 1747, which was the laſt I communicated to you of my own upon the ſubject of electricity, and which has been ſince publiſh'd in the *Philoſ. Tranſ.**, I acquainted you, that I intended upon ſome future occaſion to lay before you a ſeries of experiments in electricity made *in vacuo*; from a compariſon of which with thoſe already made in open air it did appear, that our atmoſphere, when dry, was the agent, by which, with the aſſiſtance of other electrics *per ſe*, we were enabled to accumulate electricity in and upon non-electrics; that is, to communicate to them a greater quantity of electricity than theſe bodies naturally have. That, upon the removal

---

* Numb. 485, p. 120.

removal of the air, the electricity did pervade the *vacuum* to a conſiderable diſtance, and did manifeſt its effects upon any non-electric ſubſtances, which did terminate that *vacuum*; and that by theſe means, originally-electric bodies, even in their moſt perfect ſtate, put on the appearance of non-electrics, by becoming themſelves the conductors of electricity.

I had not ſo long delayed the illuſtration of theſe opinions by the experiments, which put me in poſſeſſion of them, but that I was not only diverted therefrom by very various avocations, but deſirous of giving them a ſtill greater degree of perfection, in order to place the above deductions beyond all controverſy. The executing the apparatus neceſſary hereto was not eaſily ſurmounted: I unſucceſsfully tried ſeveral artificers, who were not able to arrive at the nicety, which I thought neceſſary in the conſtruction of my inſtruments. Animated however by a late very honourable occaſion, and aſſiſted by Mr. Smeaton in the completing my apparatus, the event fully anſwered what I propoſed; although from the experiments I had made before the communication of the above accounts, I was fully convinced of their truth. I had other opinions indeed, which did ſtill require a further degree of demonſtration.

To make theſe experiments ſucceed, two things were more particularly required; firſt, that the inſide of the glaſſes made uſe of ſhould be perfectly dry; and therefore it was neceſſary, that their internal ſurface ſhould be expoſed to the wet leathers, uſually employed in pneumatic experiments, as little as might poſſibly be; otherwiſe, the vapours, ariſing therefrom

in exhauſting, defeated the intent by conducting the electricity, and thereby preventing its accumulation. Secondly, the more complete the *vacuum* was, *cæteris paribus*, the more conſiderable were the effects: and here I ſhould not do juſtice to real merit, were I ſilent in regard to Mr. Smeaton. This gentleman with a genius truly mechanical, which enables him to give to ſuch philoſophical inſtruments, as he executes, a degree of perfection, ſcarce to be found elſewhere; this gentleman, I ſay, has conſtructed an air-pump, by which we are impower'd to make Boyle's *vacuum*, much more perfect than heretofore. By a well-conducted experiment, which admits of no doubt as to its truth, I have ſeen by this pump the air rarefied to a thouſand times its natural ſtate; whereas commonly we ſeldom arrive at above one hundred and fifty. As the promotion of the mechanic arts is a conſiderable object of our excellent inſtitution, if this gentleman could be prevailed upon to communicate to the Royal Society that particular conſtruction of his air-pump, which enables it to execute ſo much more than thoſe commonly in uſe, it would not fail to be an acceptable preſent: but to return:

The experiments treated of in this paper muſt be conſidered to have been made in this *vacuum*. The electrical machine, with its prime conductor, need here no particular deſcription; but that of the glaſs, in which the *vacuum* was made, ſhould be more minutely conſidered. It conſiſted of a glaſs tube nearly three feet in length, and of almoſt three inches in diameter. A ring of braſs, exactly fitting this tube, was cemented to both its extremities, into each of

of which was ſcrewed a hollow braſs cap, nearly of an hemiſpherical figure. Into the top of one of theſe caps was adapted a braſs box of oiled leathers, through which was admitted a ſlender braſs rod of a length ſufficient to reach within eight inches of the other extremity of the tube. Into the top of the other braſs cap was faſtened a braſs rod, like the former, only of eight inches in length. Thus the extremity of one of theſe braſs rods might at pleaſure, without letting in the air, be made to touch the other; and for the better obſerving what difference in effect would ariſe from an increaſe of ſurface, a ſmall braſs circular plate was made to ſcrew into each of theſe extremities. As the ſight of this inſtrument will convey to you at once a more clear idea than the moſt accurate deſcription, I take the liberty of laying it before you.

The intent of being able to bring the extremities of theſe rods near together, and to ſeparate them again to what diſtance you pleaſed, was, that it might without difficulty be determined, whether, and to what diſtance, the electrical fluid would manifeſt itſelf *in vacuo*, further than in air of the ſame denſity with the external.

The tube then thus fitted, and made dry both within and without, was placed in a cylinder of braſs, of about two inches long, and of a diameter juſt ſufficient to admit the braſs cap before-mentioned; and round the rim of this braſs cylinder, to prevent the ingreſs of air, was adapted a narrow piece of wet leather. Theſe being placed upon the plate of the air-pump, which ſtood upon cakes of wax, a piece of wire paſſed from the prime conductor to the long braſs

braſs rod, at the other extremity of the tube, and by theſe means, upon ſetting the electrical machine in motion, the long braſs rod in the tube was electrified. When the braſs plate at the bottom of this rod was placed near, or even at the diſtance of two inches from the plate of the other rod, the bruſhes of electrical fire were ſeen paſſing from the periphery of the upper plate to that of the lower, and every part of the air-pump ſnapped upon the touch of any one ſtanding upon the floor, and gave the other uſual ſigns of the accumulation of electricity. But, as theſe plates were made to recede from each other, this effect grew leſs and leſs; ſo that, when they were removed five or ſix inches from each other, no ſnaps could be drawn from the air-pump; as the diſſipation of the electric fluid was now as eaſy from every part of the prime conductor, as from the upper braſs plate in the tube: but it is to be noted, that this diſtance is different, as from the weather or other circumſtances the electricity is more or leſs ſtrong.

Upon exhauſting this tube, and electriſing as before the air-pump ſtill ſtanding upon cakes of wax, the electrical fire was not only ſeen to paſs from one plate to the other at the diſtance of 5 inches, but the ſame effect enſued at the greateſt diſtance, to which in the tube the braſs plates could be drawn. Being therefore deſirous to ſee a farther effect, and to avail myſelf of the whole length of this tube, I took from the inſide of it the ſhort braſs rod, to which the lower braſs plate was fixed, and faſten'd this plate at the very bottom of the tube into the cap. The conſequence was, that the electricity, meeting with ſcarce any reſiſtance, paſſed from the

top to the bottom of the tube, and electriſed the air-pump as before: and it was a moſt delightful ſpectacle, when the room was darkened, to ſee the electricity in its paſſage; to be able to obſerve, not, as in the open air, its bruſhes or pencils of rays an inch or two in length, but here the coruſcations were of the whole length of the tube between the plates; that is to ſay, thirty-two inches, and of a bright ſilver hue. Theſe did not immediately diverge as in the open air, but frequently, from a baſe apparently flat, divided themſelves into leſs and leſs ramifications, and reſembled very much the moſt lively coruſcations of the *aurora borealis*.

At other times, when the tube has been exhauſted in the moſt perfect manner, the electricity has been ſeen to paſs between the braſs plates in one continued ſtream of the ſame dimenſions throughout its whole length; and this, with a ſubſequent obſervation, ſeems to demonſtrate, that the cauſe of that very powerful repulſion of the particles of electrical fire one to the other, which we ſee in open air, is more owing to the reſiſtance of the air than to any natural tendency of the electricity itſelf; as we obſerve, that the bruſhes thereof from blunt bodies, when the electricity is ſtrong, diverge ſo much, as to form, when ſeen in the dark, an almoſt ſpherical figure. This figure ſeems therefore to ariſe from the electricity's endeavouring to inſinuate itſelf between the particles of air. The figure, that an elaſtic fluid of leſs denſity muſt form, when let looſe, and equably compreſſed by one more denſe and more elaſtic, muſt neceſſarily approach to that of a ſphere.

Upon

Upon admitting a very ſmall quantity of air into the tube, theſe phænomena diſappeared; not ſo much from the ſmall quantity of air admitted, as from the vapours, which inſinuated themſelves therewith. Theſe lined the ſides of the glaſs, and conducted the electricity imperceptibly from one end of the tube to the other. And to illuſtrate farther, that the vapours, and not the air, in the ſmall quantity admitted, occaſion'd this total diſappearing of theſe phænomena; upon experiment they have been viſible, though in a leſs perfect degree, when a much larger quantity of air was omitted to be exhauſted from the tube.

Theſe experiments ſeem to evince, that however great the *vacuum* could be made, the electrical coruſcations would pervade it through its whole length.

From hence it appears, that our atmoſphere, when dry, is the agent, by which we are enabled to accumulate electricity upon non-electrics; as in the experiment before us, upon the removal of it, the electricity paſſed off into the floor through a *vacuum*, of the greateſt length we have hitherto been able to make, became viſible in this *vacuum*, and manifeſted itſelf by its effects upon the air-pump, being the non-electric ſubſtance, which terminated that *vacuum*: whereas, when the air is not taken away, the diſſipation of the electricity is from every part of the prime conductor. We ſee here alſo, contrary to what we have found hitherto, that an originally-electric body, *viz.* a dry glaſs tube, puts on the appearance of a non-electric, by becoming itſelf the conductor of electricity, that is, by its keeping out the air, and ſuffering the electricity to pervade the *vacuum*.

How

How much ſoever the *vacuum*, here made uſe of, may exceed that, which is uſually arrived at, it is far from being a perfect one; and to make one more ſo, except that of Torricelli, which cannot without difficulty be applied to the preſent purpoſe, is not very eaſy. But it appears from the already mentioned experiments, as well as from a ſubſequent one, that the *vacuum*, which we are maſters of, does not tranſmit the electricity ſo perfectly as metals and water; as we are able to draw ſnaps from the prime conductor, an argument of ſome degree of accumulation, while the electricity is paſſing through the *vacuum*. This never happens, when metals, ſtanding upon the ground, touch the prime conductor. As we obſerve therefore, that the coruſcations diverge more or leſs, in proportion as there is more or leſs air left in the tube, this effect may ariſe even from the ſmall quantity of air ſtill remaining undiſcharged.

I was deſirous of knowing, for the farther illuſtration of my propoſitions, whether the experiment of Leyden could be made through the *vacuum*. For this purpoſe I made the before-mention'd exhauſted tube part of the circuit, ſo neceſſary to this experiment. What this circuit is, I have in my former communications ſo often and ſo clearly exemplified, that it would be needleſs to repeat it here. You know in this experiment it is likewiſe abſolutely neceſſary, that the whole quantity, or nearly ſo, of the accumulated electricity ſhould be diſcharged in the ſame inſtant of time. Accordingly, upon making the experiment, at the inſtant of the exploſion, you ſaw a maſs of very bright embodied fire jump from one of the braſs plates in the tube to the other: but this did not take place, when one of the plates was

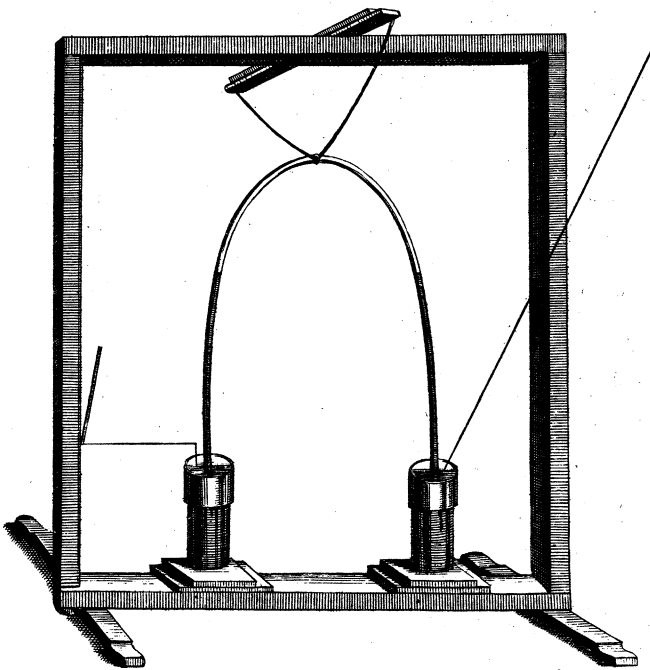
farther diſtant from the other than ten inches. If the diſtance was greater, the fire then began to diverge, and loſe part of its force; and this force diminiſhed in proportion to its divergency, which was nearly as the diſtance of the two plates.

The difficulty however of applying the Torricellian *vacuum* to theſe experiments has been happily got over by the right honourable the Lord Charles Cavendiſh, our worthy Vice-preſident. This noble lord, who to a very complete knowlege of the ſciences joins that of the arts, and whoſe zeal for the promotion of true philoſophy is exceeded by none, has applied it in the following manner, and his lordſhip has had the goodneſs to put his apparatus into my hands. This apparatus conſiſted of a cylindrical glaſs tube of about three tenths of an inch in diameter, and of ſeven feet and half in length, bent ſomewhat like a parabola in ſuch a manner, that thirty inches of each of its extremities were nearly ſtraight, and parallel to each other, from which an arch ſprung, which was likewiſe of thirty inches *. This tube was careſully fill'd with mercury; and each of its extremities being put into its baſon of mercury, ſo much of the mercury ran out, until, as in common barometrical tubes, it was in equilibrio with the atmoſphere. Each of the baſons containing the mercury was of wood, and was ſupported by a cylindrical glaſs of about four inches in diameter, and ſix inches in length; and theſe glaſſes were faſten'd to the bottom of a ſquare wooden frame, ſo contrived, as that to its top was ſuſpended by ſilk lines the tube filled with

* See the repreſentation of this apparatus, Tab. XVI.

Philos. Trans. Vol. XLVII. TAB. XVI.

p. 370.



J. Mynde sc.

with mercury before-mention'd; ſo that the whole of this apparatus without inconvenience might be moved together. The Torricellian *vacuum* then occupied a ſpace of about thirty inches. In making the experiment, when the room was darkened, a wire from the prime conductor of the common electrical machine communicated with one of the baſons of mercury, and any non-electric touching the other baſon, while the machine was in motion, the electricity pervaded the *vacuum* in a continued arch of lambent flame, and as far as the eye could follow it, without the leaſt divergency.

That the electricity was not furniſhed from the glaſſes employed in theſe operations, nor from the circumambient air, I have heretofore, in my communications to you upon this ſubject, endeavoured to evince. I have ſhewn, that electricity is the effect of a very ſubtil and elaſtic fluid, occupying all bodies in contact with the terraqueous globe; and that every-where, in its natural ſtate, it is of the ſame degree of denſity; and that glaſs and other bodies, which we denominate electrics *per ſe*, have the power, by certain known operations, of taking this fluid from one body, and conveying it to another; in a quantity ſufficient to be obvious to all our ſenſes: and that, under certain circumſtances, it was poſſible to render the electricity in ſome bodies more rare than it naturally is, and, by communicating this to other bodies, to give them an additional quantity, and make their electricity more denſe: and that theſe bodies will thus continue until their natural quantity is reſtored to each; that is, by thoſe, which have loſt part of theirs, acquiring what they have loſt;

and by thoſe, to which more has been communicated, parting with their additional quantity. Both one and the other of theſe is, from the elaſticity of the electric matter, attempted to be done from the neareſt non-electric; and when the air is moiſt, this is ſoon accompliſhed, by the circumambient vapours, which here may be conſidered as preventing in a very great degree our attempts to inſulate non-electric bodies. But theſe matters I have copiouſly treated of in my former communications upon this ſubject *: this ſhort recapitulation however I thought neceſſary, for the more eaſy illuſtrating what I propoſe to ſubjoin; and it is upon theſe principles that we are able to account for the circulation of electricity deſcribed in the *Philoſophical Tranſactions*, Vol. XLIV. p. 740.

If therefore the before-mention'd principles are true, and if the electricity is not furniſhed by the globe in its rotation, nor by the air, it ought to be viſible in the *vacuum* of the before-deſcribed glaſs tube, in its ingreſs to the frame of the electrifying machine, if this machine, and the man who turns the wheel thereof, are ſupported by electrics *per ſe*, and if, during this operation, the electricity, as faſt as furniſhed, is taken off by a byſtander, or otherwiſe, from the prime conductor; as under theſe circumſtances the *vacuum* is the only paſſage open to its progreſs, and from its elaſticity the electricity ſhould protrude itſelf through it. And from experiment this is the caſe; for, upon a piece of wire being connected with the end of the long braſs rod,

* See *Phil. Tranſ.* Vol. XLV. pag. 95 *& ſeq.*

rod, or with the braſs cap at the upper extremity of that tube, and the other end of the wire faſtened to any part of the frame of the electrifying machine, and this laſt put in motion, the electrical coruſcations are ſeen to paſs as before from one of the braſs plates contained in the tube to the other; and to continue, unleſs the air inſinuates itſelf, as long as the machine is in motion. If, under theſe circumſtances, the hand of a perſon ſtanding upon the floor is brought near the ſides of the glaſs, the coruſcations will direct themſelves that way in great variety of forms, extremely curious to behold. But here, as in the former experiment, our *vacuum* did not conduct ſo perfectly as metals or water; as a perſon, ſtanding upon the floor, and applying his finger to the upper braſs cap of the tube, receives a ſmart ſtroke: and this I conceive to ariſe, from the electricity of this braſs being ſo much more rarefied, or attenuated, than that of the body of the man, applying his finger.

This experiment ſhould be made in the middle of a large room, and the machine, and man turning it, ſhould be raiſed from the floor at leaſt a foot: otherwiſe the effects deſired will be diminiſhed by the electricity being in part furniſhed by the floor to the machine.

To what is here laid down it may be objected, that the electrical coruſcations in the laſt experiment proceed, not from the floor of the room, as I have conjectured, but from the electricity being, from the globe in motion, diffuſed at the ſame time upon the prime conductor, as well as all over the machine, and which in the tube becomes viſible in its paſſage

to the floor. But it is to be remember'd in this experiment, that no electricity is perceptible either *in vacuo*, or upon any part of the machine, as above-mentioned, unleſs at the ſame time the prime conductor is made uſe of; for, without that, there will be no diminution of the denſity of the electricity in the machine, as the quantity taken from the cuſhion by the globe in its rotation is returned upon it again the next revolution, the cuſhion being the firſt non-electric, which offers itſelf: but this I have have conſider'd at large, as may be ſeen in the *Philoſophical Tranſactions* *. This experiment therefore, in which the electricity is ſeen, without any preternatural force, puſhing itſelf on through the *vacuum* by its own elaſticity, in order to maintain the equilibrium in the machine, which had loſt part of its natural quantity of electricity by the preſent operation; this experiment, I ſay, I do not ſcruple to conſider as an *experimentum crucis* of the truth of the doctrines here laid down; to wit, not only that the electricity is furniſh'd by thoſe bodies, hitherto called non-electrics, and not by the electrics *per ſe* ‖; but

* Vol. XLV. p. 96.

‖ Since the communication of this paper to the Royal Society in February 1752, *viz.* in the ſucceeding ſummer, the truth of this doctrine is put out of all doubt by the diſcovery made in France, in conſequence of Mr. Franklin's hypotheſis, of being able, by a proper apparatus, to collect the electricity from the atmoſphere during a thunder-ſtorm, and to apply it to the uſual experiments, which demonſtrates, that the matter of thunder and lightning and that of electricity are one and the ſame. That the electricity did not proceed from the glaſs, or other electrics *per ſe*, as they had been uſually called, I firſt diſcover'd in the year 1746: See

but alſo, that we are able to add to, or take from, that quantity of electricity, naturally adherent to bodies.

By what denomination ſhall we call this extraordinary power? From its effects in theſe operations, ſhall we call it electricity? From its being a principle neither generated nor deſtroyed; from its being every-where and always preſent, and in readineſs to ſhew itſelf in its effects though latent and unobſerved, till by ſome proceſs it is produced into action, and rendered viſible; from its penetrating the denſeſt and hardeſt bodies, and its uniting itſelf to them; and from its immenſe velocity; ſhall we, with Theophraſtus, Boerhaave, Niewentyt, s'Graveſande, and other philoſophers, call it elementary fire? Or ſhall we, from its containing the ſubſtance of light and fire, and from the extreme ſmallneſs of its parts, as paſſing through moſt bodies we are acquainted with, denominate it, with Homberg and the chemiſts, the chemical ſulphureous principle, which, according to the doctrines of theſe gentlemen, is univerſally diſſeminated? We need not indeed be very ſollicitous in relation to its denomination: certain it is, that the power we are now treating about is, beſides others, poſſeſſed of the properties before-mentioned, and cannot

---

See *Phil. Tranſ.* Vol. XLIV. p. 713.—749, and explained further Vol. XLV. p. 95, *et ſeq.* and though the electric matter may be taken from the atmoſphere during a ſtorm of thunder, or even when it is only charged with what are uſually called thunder-clouds, that is, when the atmoſphere is replete with heterogeneous phlogiſtic matter, yet it muſt not be conſidered as coming from pure dry air, which, as I before mentioned, I conceive to contain in its natural ſtate ſcarce any of the electric matter, and is the agent, by which we are enabled to communicate electricity to other bodies.

cannot but be of very great moment in the ſyſtem of the univerſe.

I am, Gentlemen, with all poſſible reſpect,

London, Feb. 12, 1752. Your moſt obedient humble ſervant,

W. Watſon.

LXII. *A Letter from Dr.* Bevis *to Dr.* De Caſtro, *F. R. S. containing Extracts of Father* Auguſtin Hallerſtein's *aſtronomical Obſervations made at* Pekin *in* 1744 *and* 1747.

Read March 5, 1752. I AM much obliged to you, Sir, for furthering F. Aug. Hallerſtein's letter to me. It informs me, that the inſtrument I wrote the deſcription and uſe of, was arrived ſafe at Pekin. According to that miſſionary's requeſt, I have carefully looked over the obſervations he ſent to Dr. Sanchez at Paris, to be communicated to the Royal Society through your hands. They are compariſons of all the planets with known fix'd ſtars taken in the Jeſuit's College at Pekin, in 1746 and 1747, with a well-adjuſted pendulum-clock, and a micrometer; and appear to me to have been done with judgment and accuracy